1-1-2010

Buoyancy-driven flows in pipelines - effect on hydrostatic test measurements

Ajit Godbole
University of Wollongong, agodbole@uow.edu.au

Paul Cooper
University of Wollongong, pcooper@uow.edu.au

Phillip Venton
Venton and Associates

John Hough
Saipem

3634 2

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the australian PIPELINE industry association Ltd

APIA Research and Standards Committee Seminar

Tuesday 8 June 2010
iC City View Room
University of Wollongong

"APIA-RSC 3RD RESEARCH SEMINAR"

APIA-RSC Seminar 2010

Over the past three years, the APIA Research and Standards Committee has organised an annual Seminar for the purpose of exposing and introducing a wide audience within the APIA-RSC community to the research activities currently being undertaken by the industry. The APIA-RSC is mindful of the importance for the industry's younger engineers employed by RSC members to be provided with the opportunity to learn about the research activities. It is the hope and intention that, by attending the Seminars this will enable the younger engineers to become more involved in the process of identifying research needs and implementing the outcomes.

This initiative is part of the wider movement within APIA to address the serious skills shortage that we face and to encourage succession planning. With the establishment of the Energy Pipelines CRC, the annual seminars will continue to be held each year jointly between the EPCRC and the APIA-RSC .

Who should attend?

This seminar will benefit a range of employees of the member organisations of the APIA Research and Standards Committee. It provides an excellent opportunity for the younger staff to learn about the status and depth of the APIA research activities while meeting and networking with leading industry researchers and research providers.

The APIA-RSC nominated representatives for each member organisation are asked to arrange for their staff to be able to attend, and especially to encourage YPF members to participate.

Dinner

There will be an APIA-RSC Dinner following the Seminar for all participants and this will be held in the Admirals Room at the Novotel Wollongong Northbeach. The dinner will commence with pre-dinner drinks at 6.30pm followed by dinner at 7.00 p.m. The Guest Speaker at the dinner is Jim McDonald, Chair, Energy Pipelines CRC. He will be speaking on **"Management of the Tennant Creek earthquake damage to the Darwin pipeline in 1988"**

Venue and Accommodation

This year's APIA-RSC dinner and Committee meeting will be held at the Novotel Wollongong Northbeach. APIA-RSC delegates can receive a discounted room rate. To take advantage of the discounted rate please call Amy Whitehouse on 02 4224 3159 and say you are attending the APIA Event. Accommodation is the responsibility of the delegate and all room charges are to be settled prior to departure from the hotel.

Novotel Wollongong Northbeach 2-14 Cliff Road, North Wollongong
P: 02 4224 3159 **E:** H1654-SB05@accor.com

Registration Details (Please Tick) Must RSVP by 1 June 2010

Researchers: □ **Seminar $0** □ **Dinner $ 110**

APIA-RSC Members : □ **Seminar $0** □ **Dinner $ 110**
(Including additional APIA –RSC member employees)

Non APIA Members □ **Dinner $ 130**

Registration Details

Surname Name

PLEASE ATTACH LIST IF INSUFFICIENT ROOM

Company

Postal Address

Suburb Postcode

Telephone Fax

Email

Dietary Requirements

□ I have transacted or will be transacting an Electronic Funds Transfer to the APIA Account.
Bank: Westpac Branch: Manuka BSB: 032 729 Account Number: 162756 Swift Code: WPACAU2S

□ Enclosed is a cheque

□ Please debit my AMEX/Diners/Visa/Mastercard Amount

Card No Expiry

Cardholder Name Signature

Please return form to:
APIA
PO Box 5416, Kingston ACT 2604
T: 02 6273 0577

ABN: 29 098 754 324
E: events@apia.asn.au
F: 02 6273 0588

A tax invoice will be issued on receipt of booking form. Bookings and cancellations received prior to 1 June 2010 will be fully refunded. Cancellations after this time will not be refundable, however, substitutions will be accepted.

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"APIA-RSC 3RD RESEARCH SEMINAR"

Con Pub
(General)
Presentat

Buoyancy-Driven Flows in Pipelines - Effect on Hydrostatic Test Measurements

Researchers:

Dr Ajit Godbole
Prof Paul Cooper

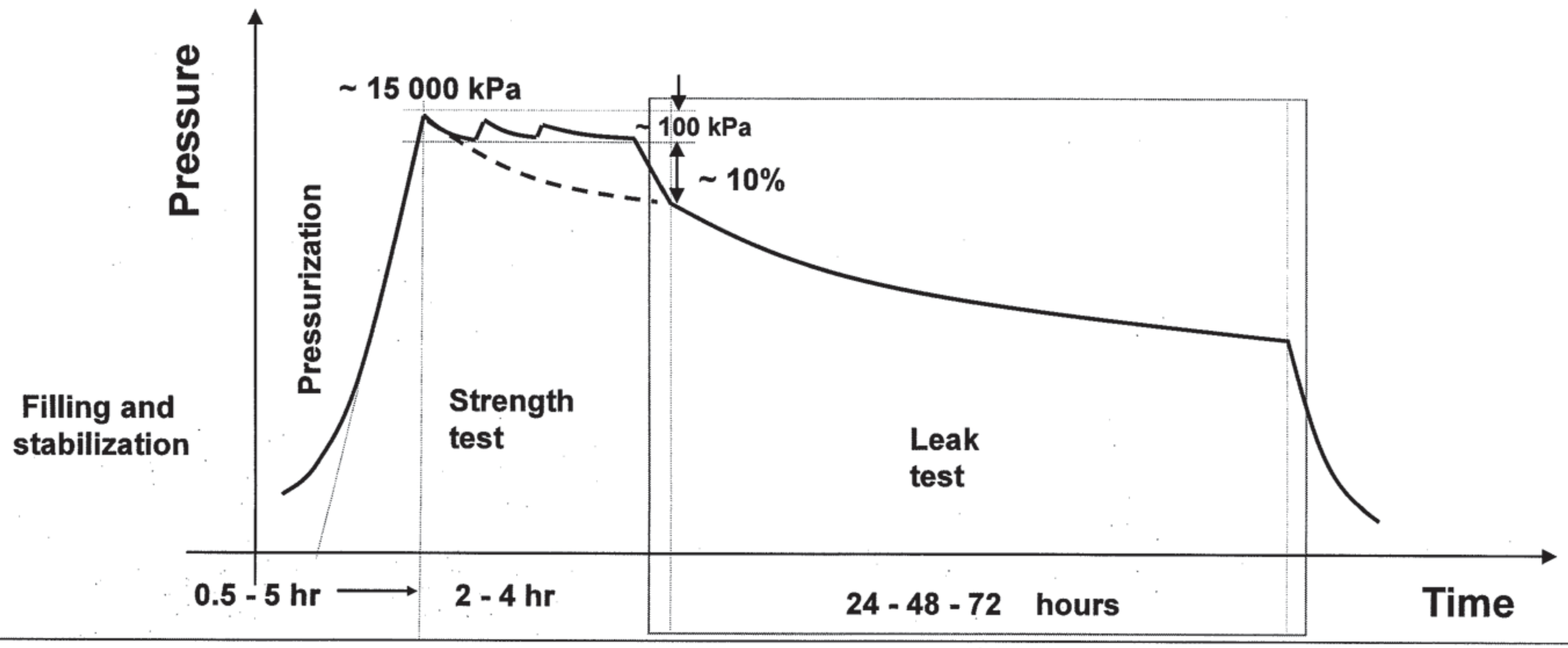
Industry Advisors:
Philip Venton
Venton and Associates

John Hough
Saipem

Background

- Hydrostatic Test - to ascertain that a pipeline is capable of withstanding the pressure for which it is designed
  - to ensure that it is leak-free
- Typical hydrostatic test on an isolated pipeline test section:

  - Filling
  - Stabilization
  - Pressurization
  - Strength Test
  - Leak Test

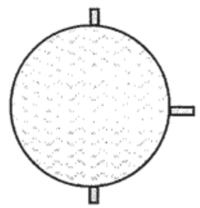


Background

- Measurement of test fluid pressure and temperature.
- Pressurization → heating of the test fluid due to adiabatic compression;
  → cooling of the pipe due to stretching.
- Leak → drop in measured test section pressure
- Change in measured temperature a major contributor to perceived change in pressure
- *Especially for large test sections and over long time durations, other factors can contribute to the magnitude of change in the measured values, apart from a leak, if any.*

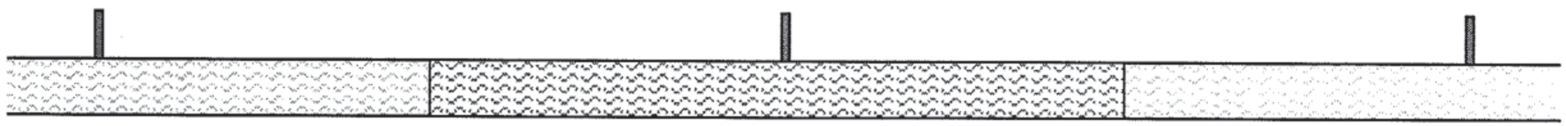
Background

- These factors include:
  - Location of measuring instrument along pipe 
  - Time of measurement 
  - Changes in pipeline/fitting shape with temperature 
  - Soil characteristics in case of buried pipeline 
  - Fraction of exposed length 
  - Diurnal changes 

  etc.
- Apart from these …
  - Location of measuring instrument at any cross section 

- AS 2885.5: Measurement of bulk temperature of test fluid at a number of discrete points along the pipeline

- *Assumption: pipe <u>wall</u> temperature measured at a location adequately represents the bulk <u>fluid</u> temperature at that point, and at locations on either side of that point for a distance half of location separation.*



- Measurement locations separated by very long distances

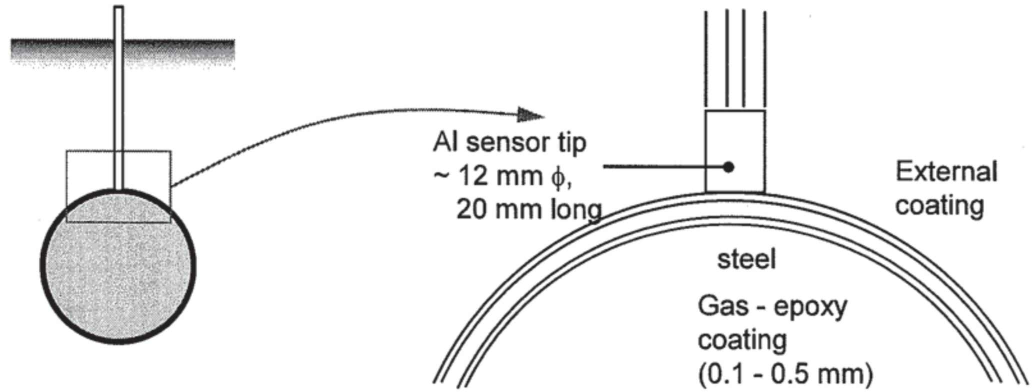
- Pipeline buried underground ~ 1-2 m

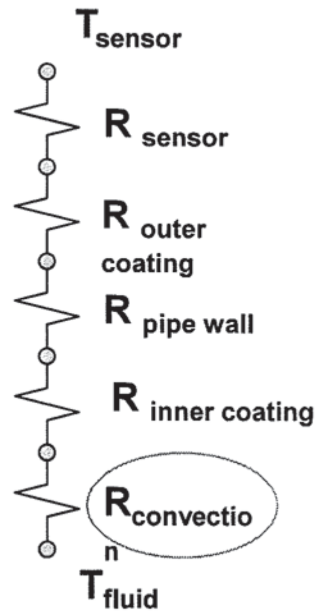
Purpose

To determine and quantify the error associated with the assumption that the pipe wall temperature gives a fair indication of the bulk water temperature at that location

Temperature Measurement

- Probe location – usually topmost point on outer surface of (coated) pipeline (closest to soil surface)

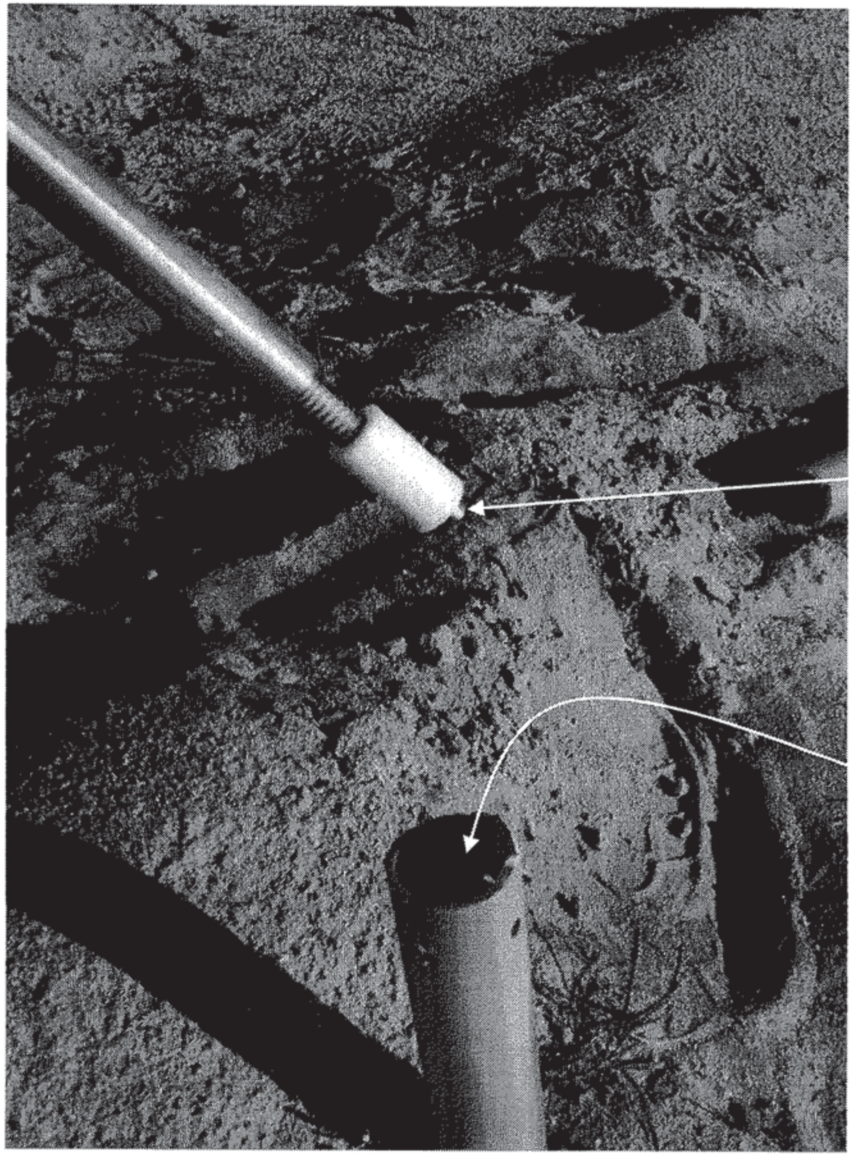




- Thermal resistances between probe tip and test fluid

- Measured temperature likely to be different from bulk water temperature.

Temperature Measurement



Measuring tip
mounted on
spring-loaded rod

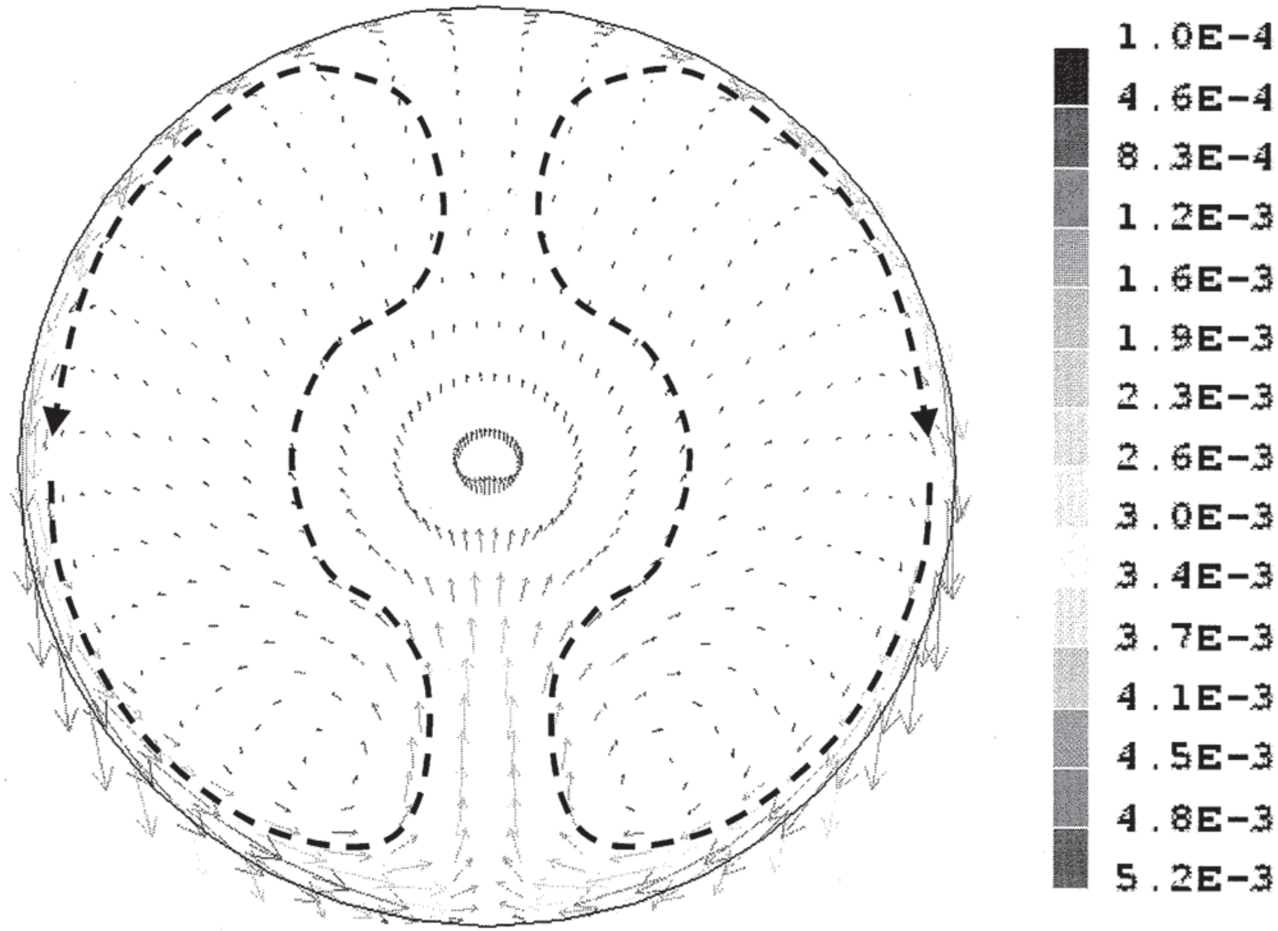
Hole reaches top surface
of buried pipeline

Buoyancy-driven flows

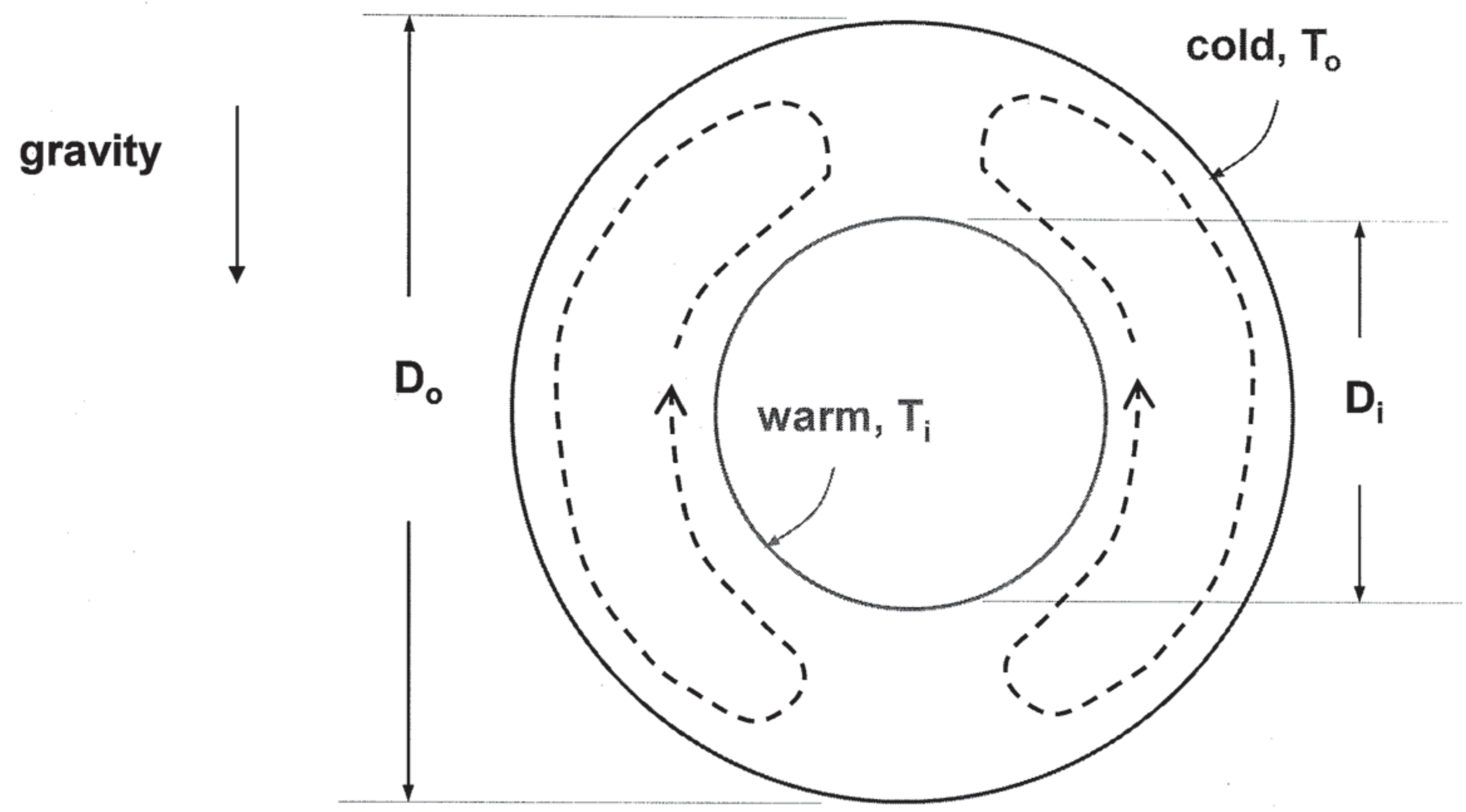
- Internal flows in the water due to initial temperature difference
- Flow driven purely by buoyancy effects
- Heat transfer to/from water in 'film' adjacent to pipe wall
  → slight change in density, compared to that of bulk water
- Resulting buoyancy forces initiate flow which spreads into fluid body due to viscosity
- Different flow conditions at different points around pipe wall inner surface
- Variation in heat transfer coefficient around pipe wall circumference
- Effect accentuated in *inclined* pipelines

Typical Flow Field – Water initially warmer than pipe/soil

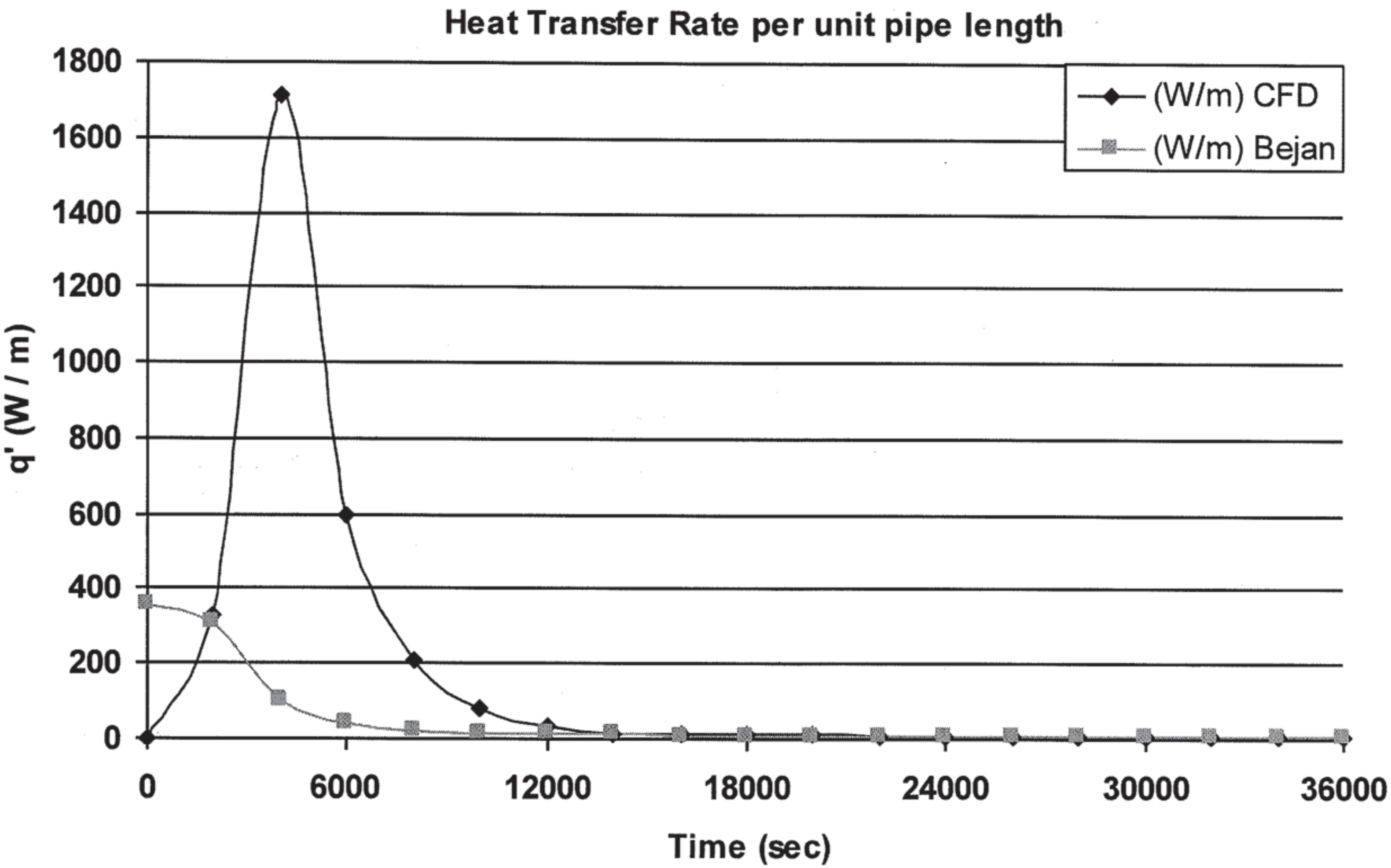
Horizontal pipe



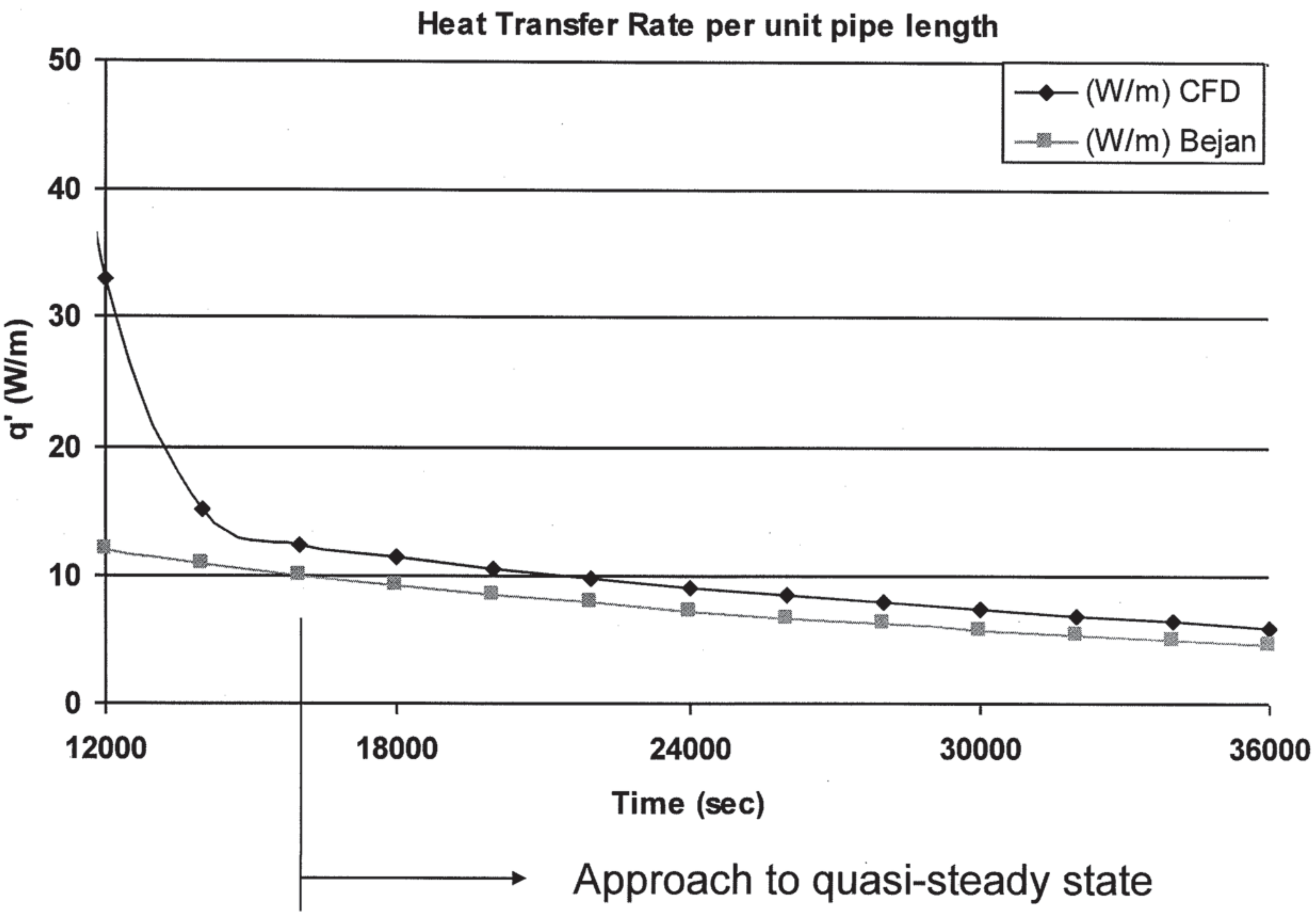
Partial Validation – Flow in Concentric Annulus (Bejan, 2004)



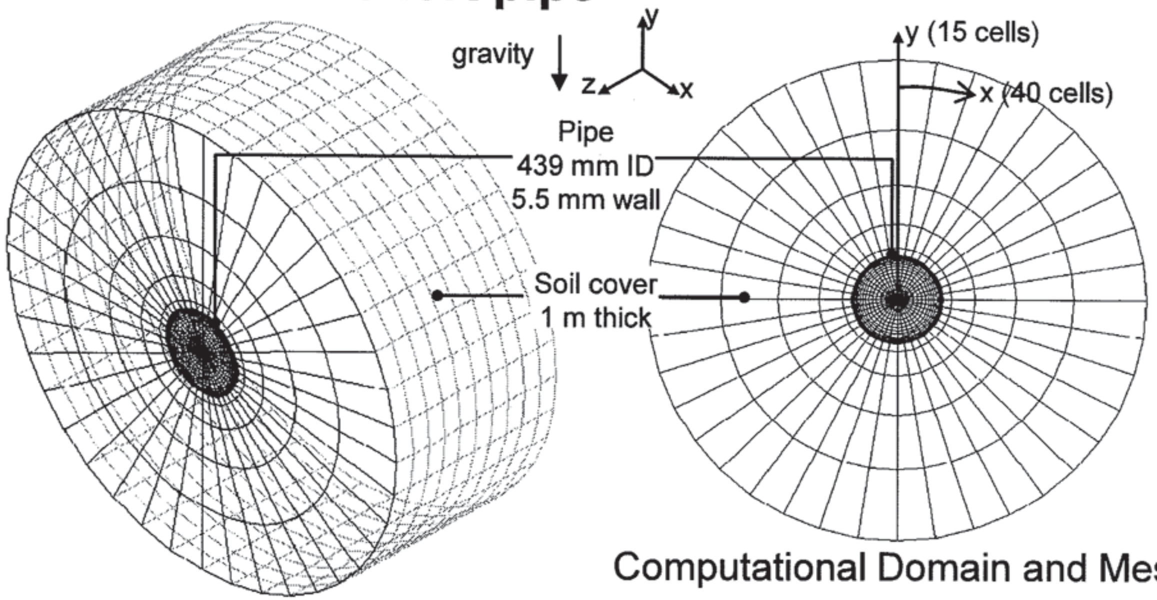
Variation of Heat Transfer / Unit Length w.r.t. time



Variation of Heat Transfer / Unit Length w.r.t. time

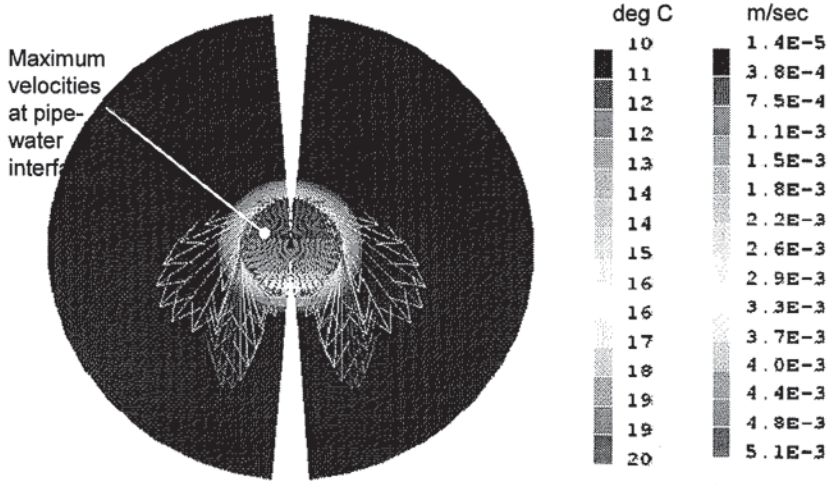


Horizontal buried short pipe

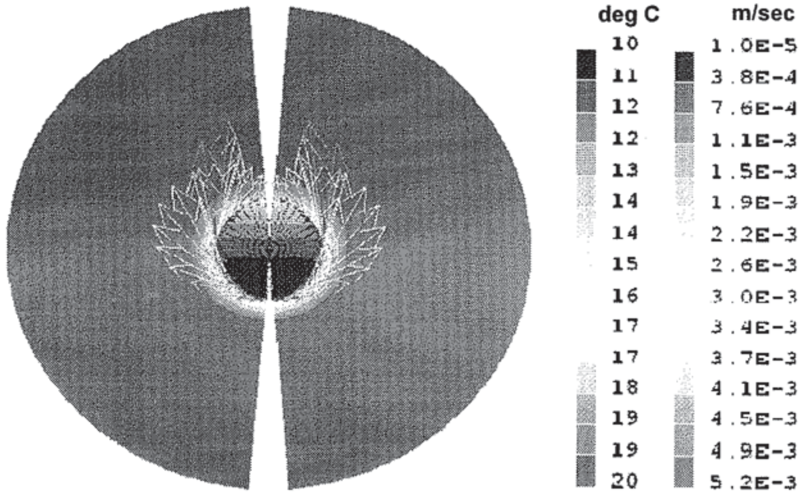


Computational Domain and Mesh

- Initially warmer water, cooler pipe/soil

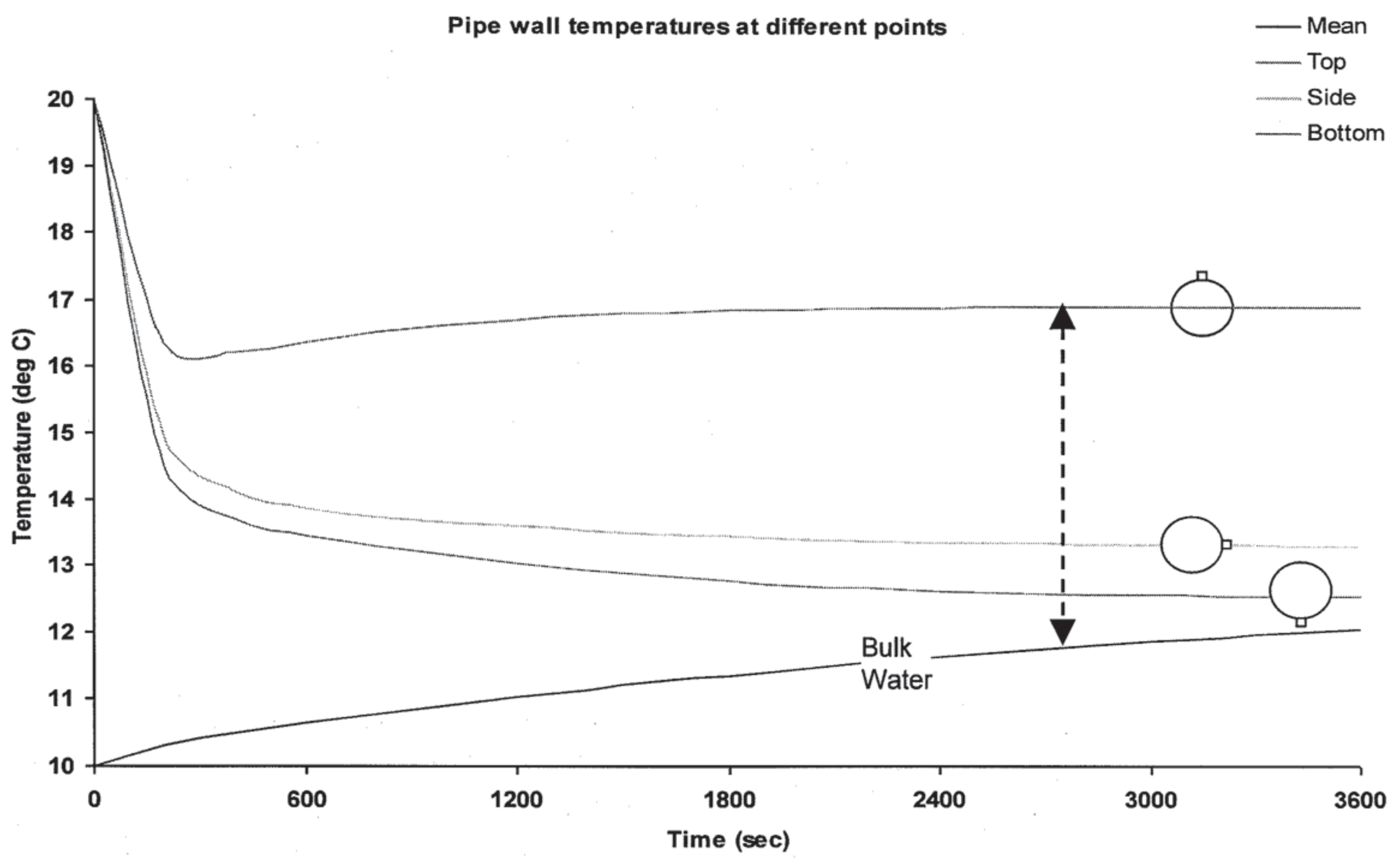


- Initially cooler water, warmer pipe/soil



Flow and thermal fields at 2000 sec from start

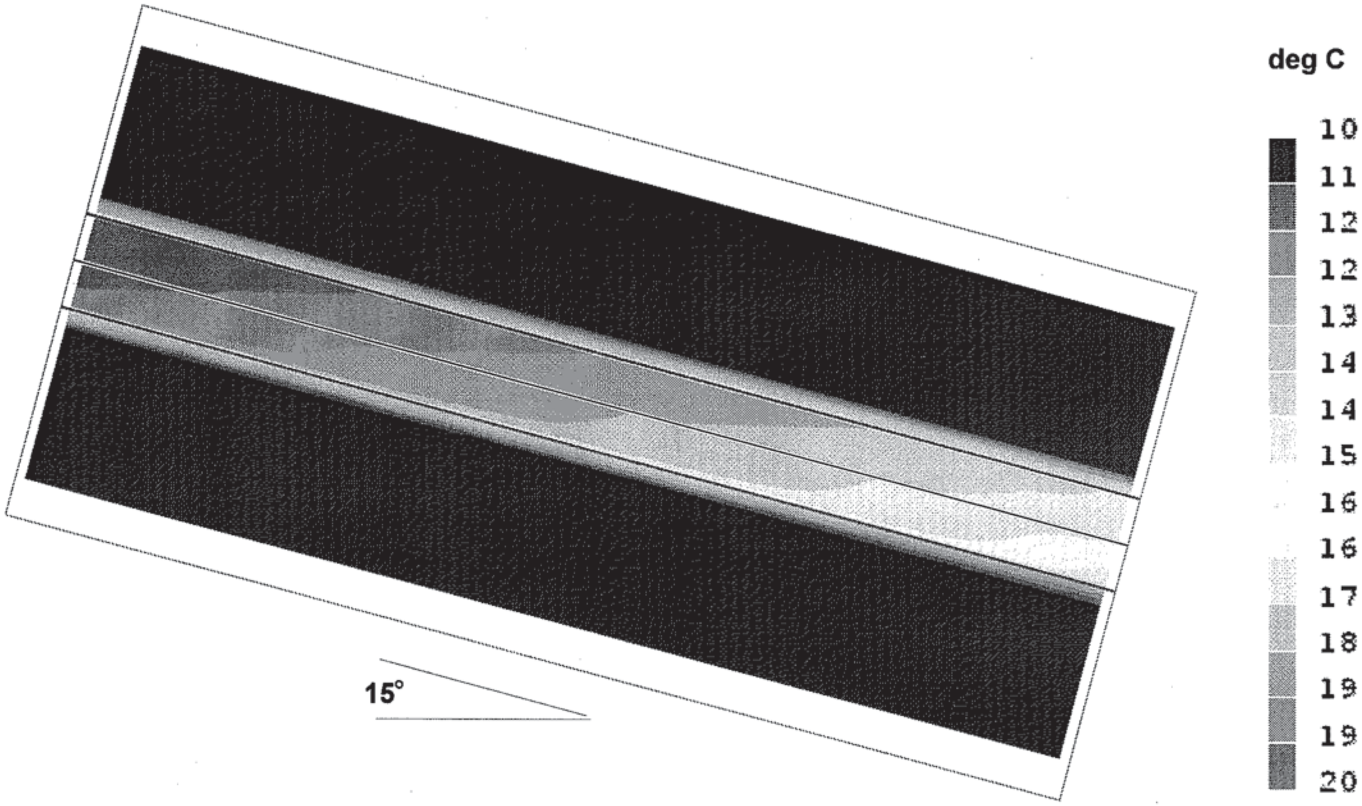
Horizontal buried short pipe (initially cooler water, warmer pipe/soil)



Temperature trends over one hour

Inclined, buried longer pipe section

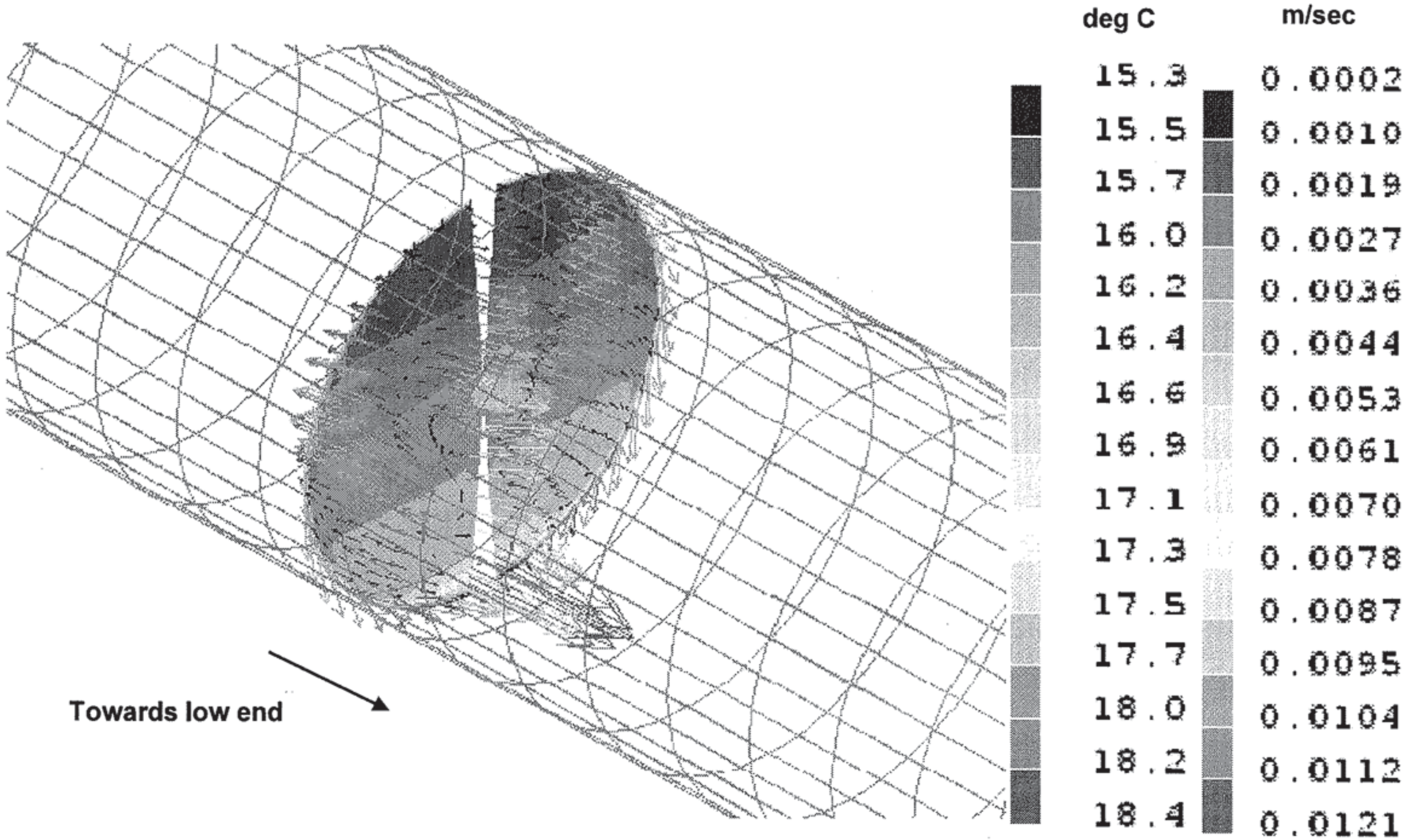
- Initially warmer water, cooler pipe/soil



Temperature stratification in near-vertical plane after one hour

Inclined, buried longer pipe section

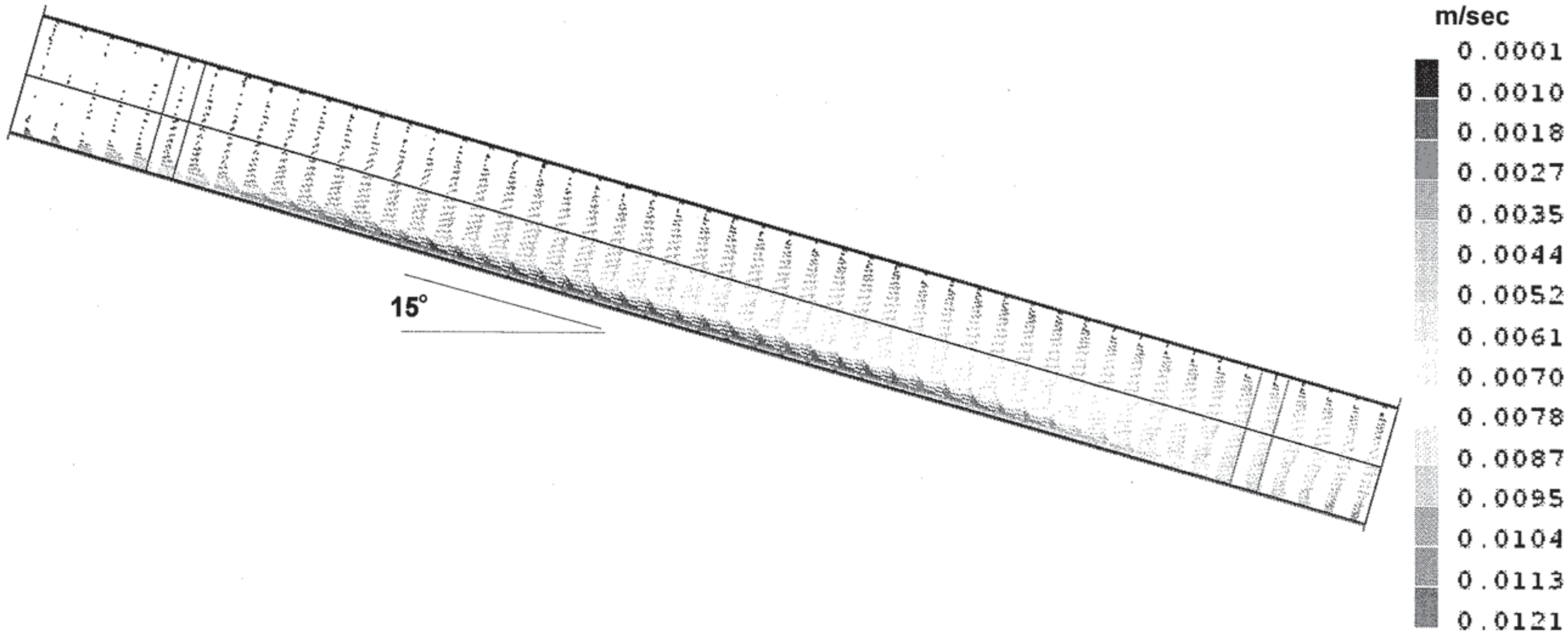
- Initially warmer water, cooler pipe/soil



Flow and temperature fields at mid section after one hour

Inclined, buried longer pipe section

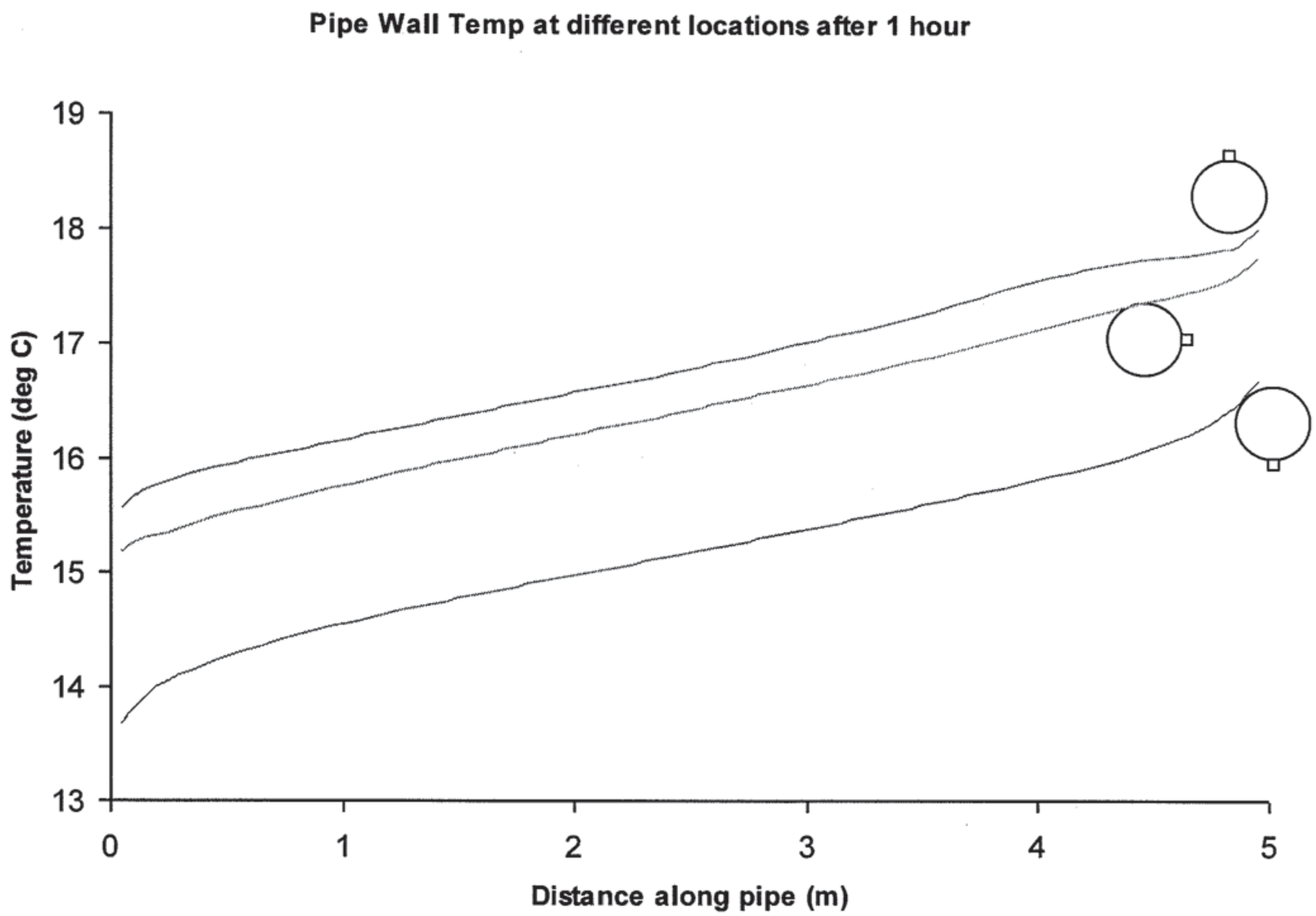
- Initially warmer water, cooler pipe/soil



Velocity vectors in near-vertical central plane after one hour

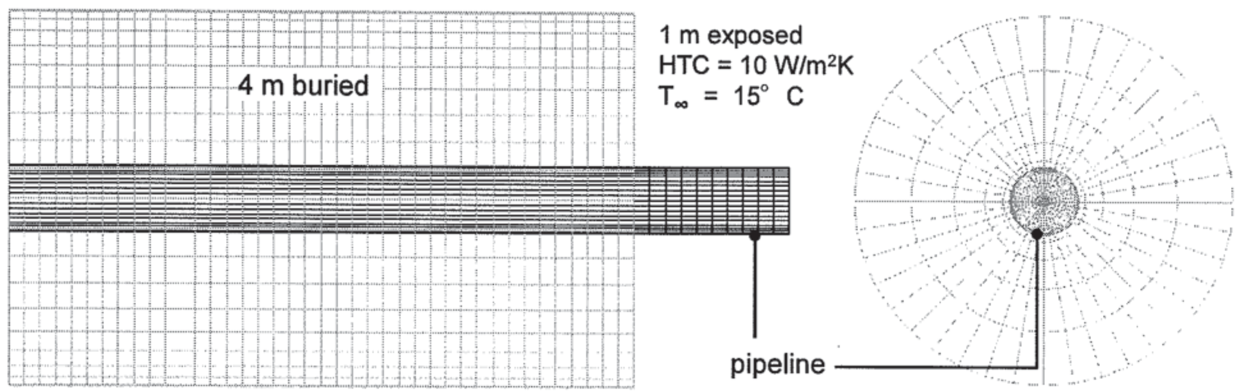
Inclined, buried longer pipe section

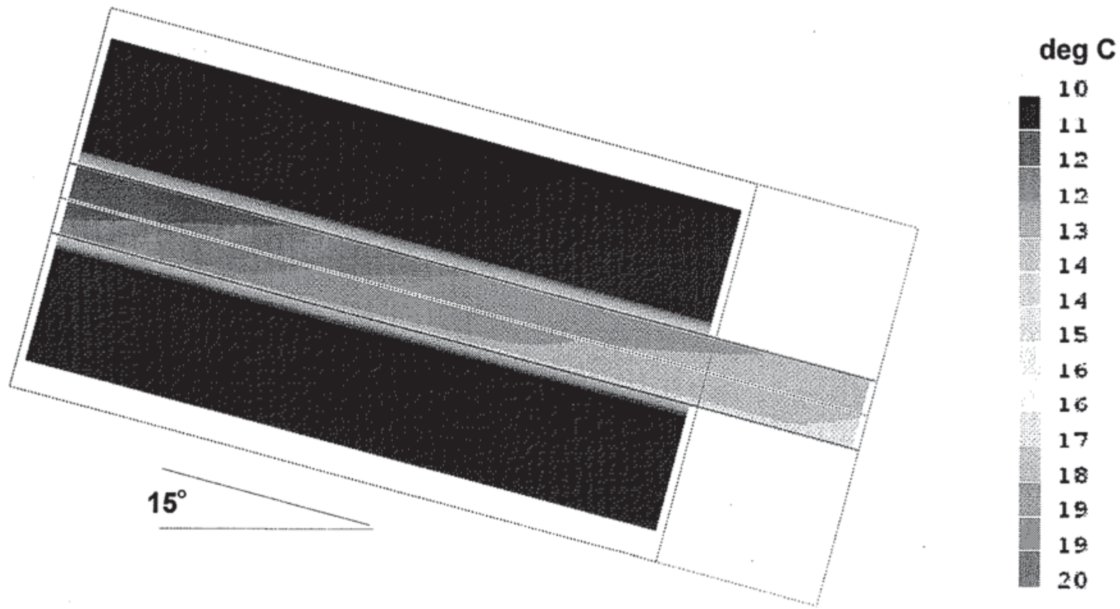
- Initially warmer water, cooler pipe/soil



Inclined, partly buried longer pipe section

- Exposed low end

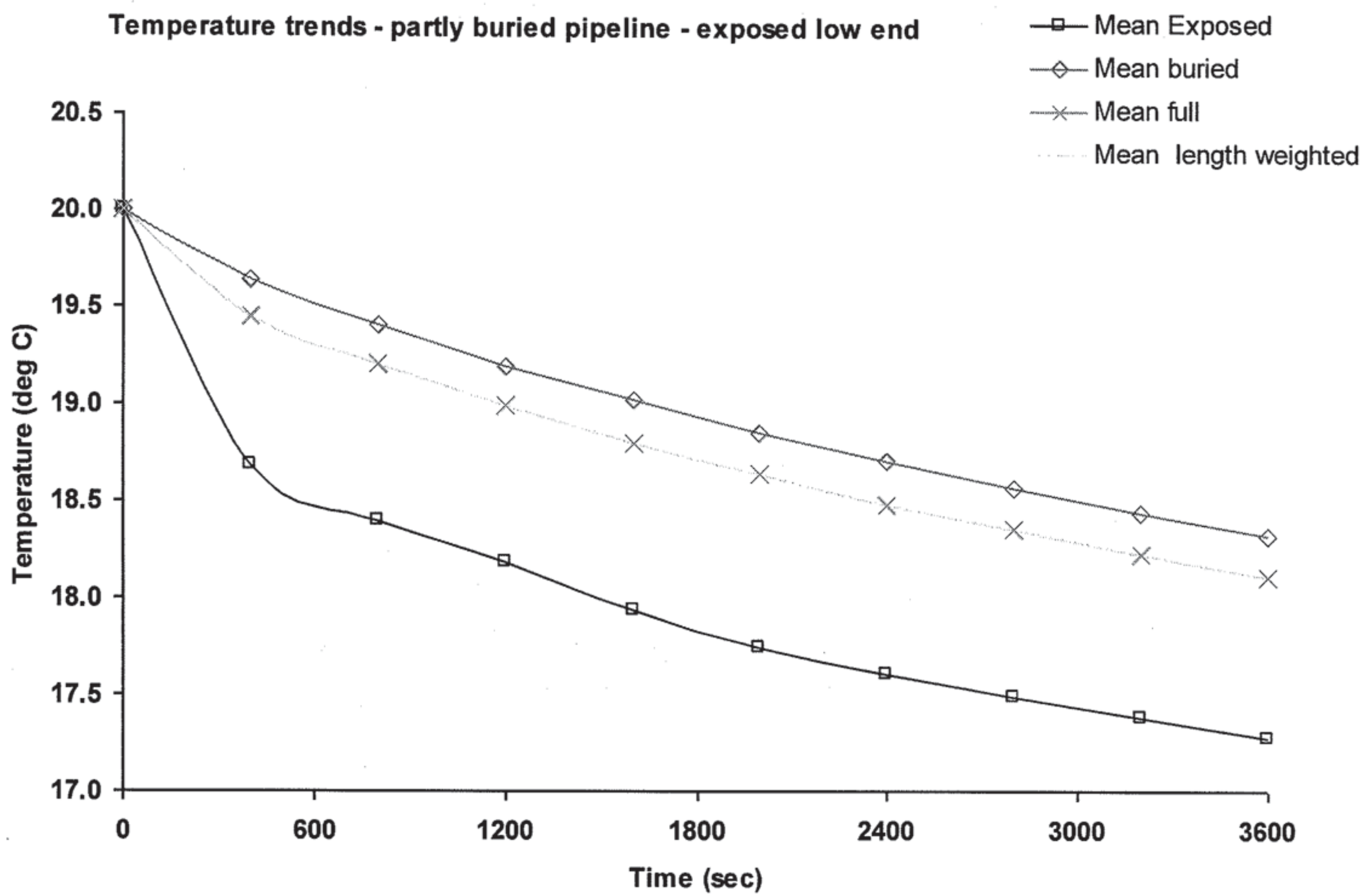




Flow and temperature fields at mid section after one hour

Inclined, partly buried longer pipe section

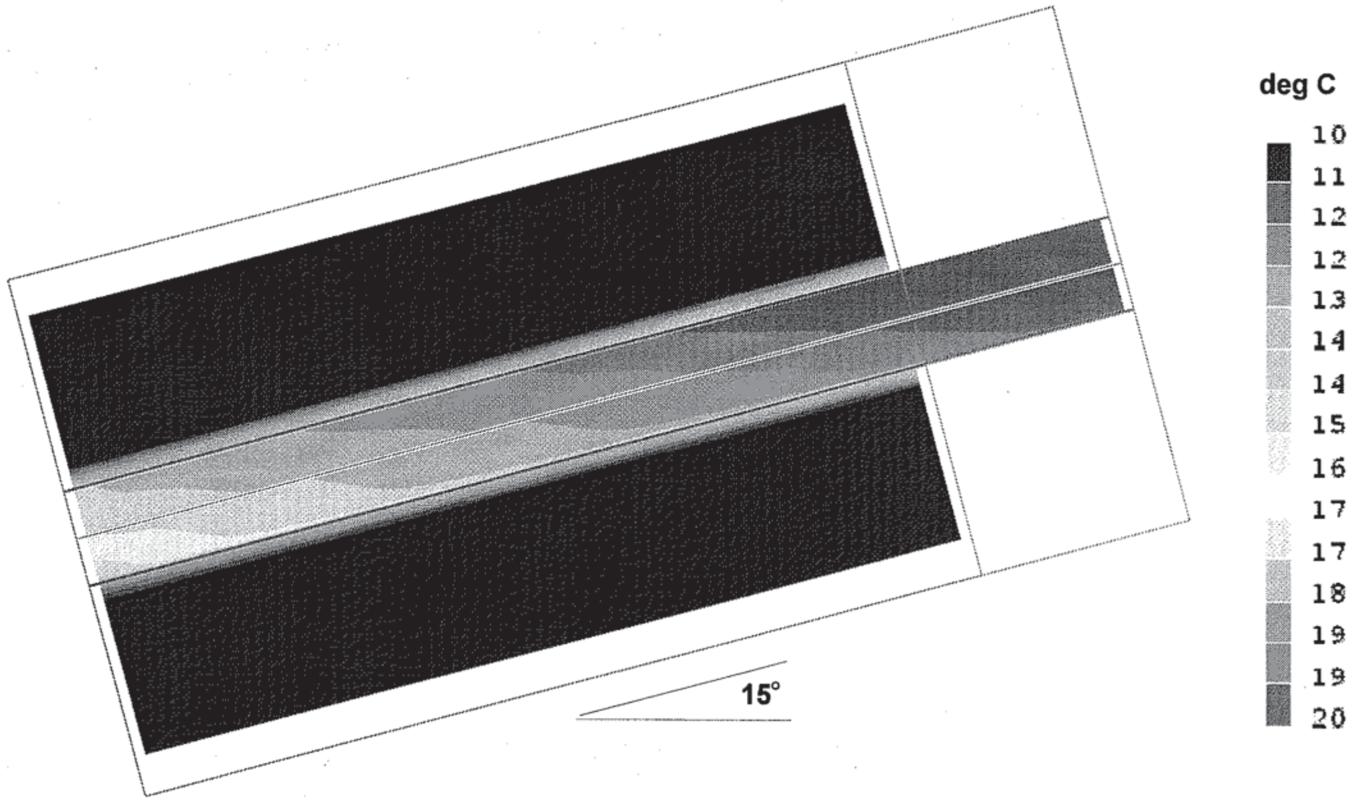
- Exposed low end



Variations in ‘mean’ temperatures over time

Inclined, partly buried longer pipe section

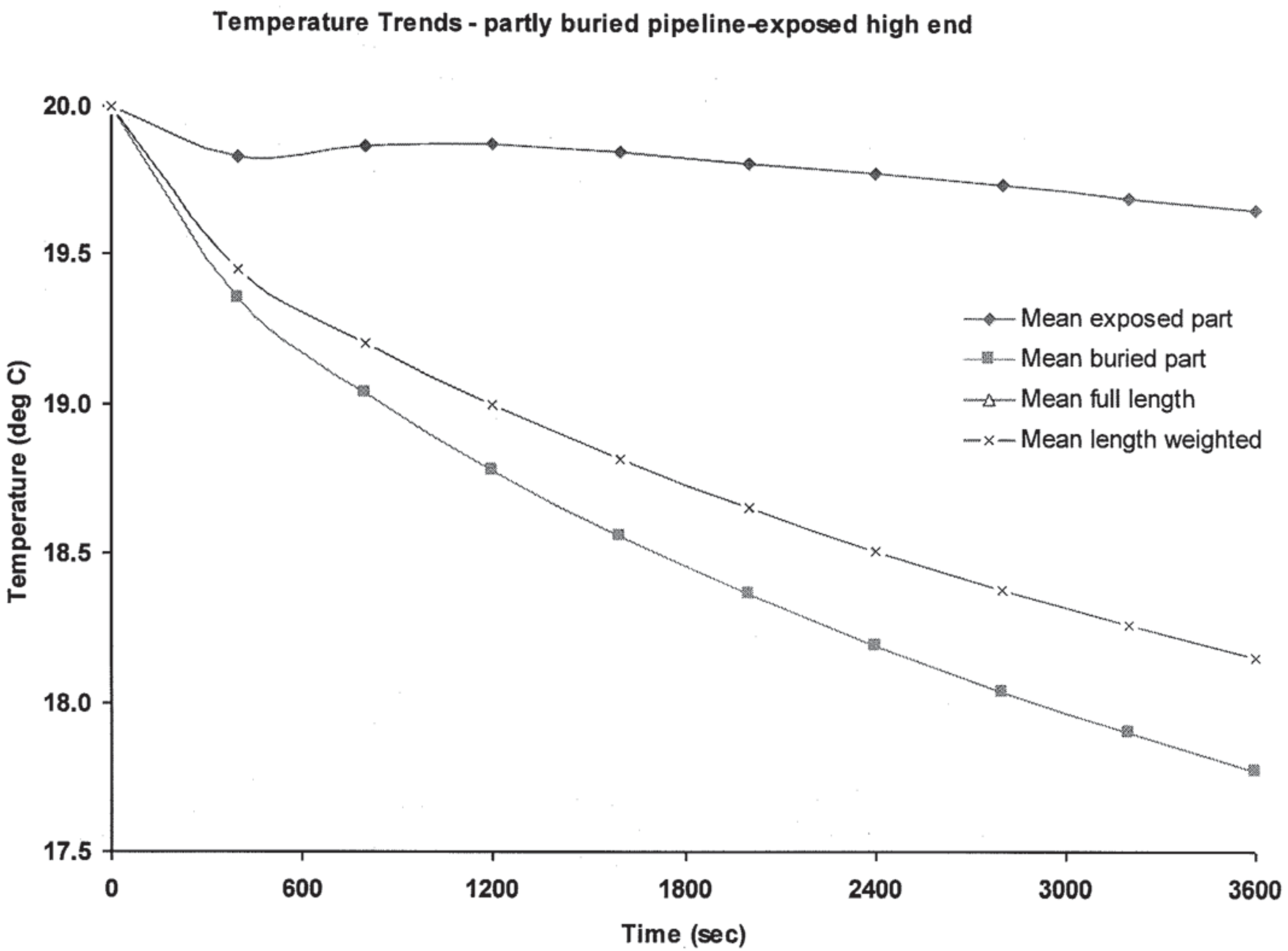
- Exposed high end



Thermal stratification in near-vertical plane after one hour

Inclined, partly buried longer pipe section

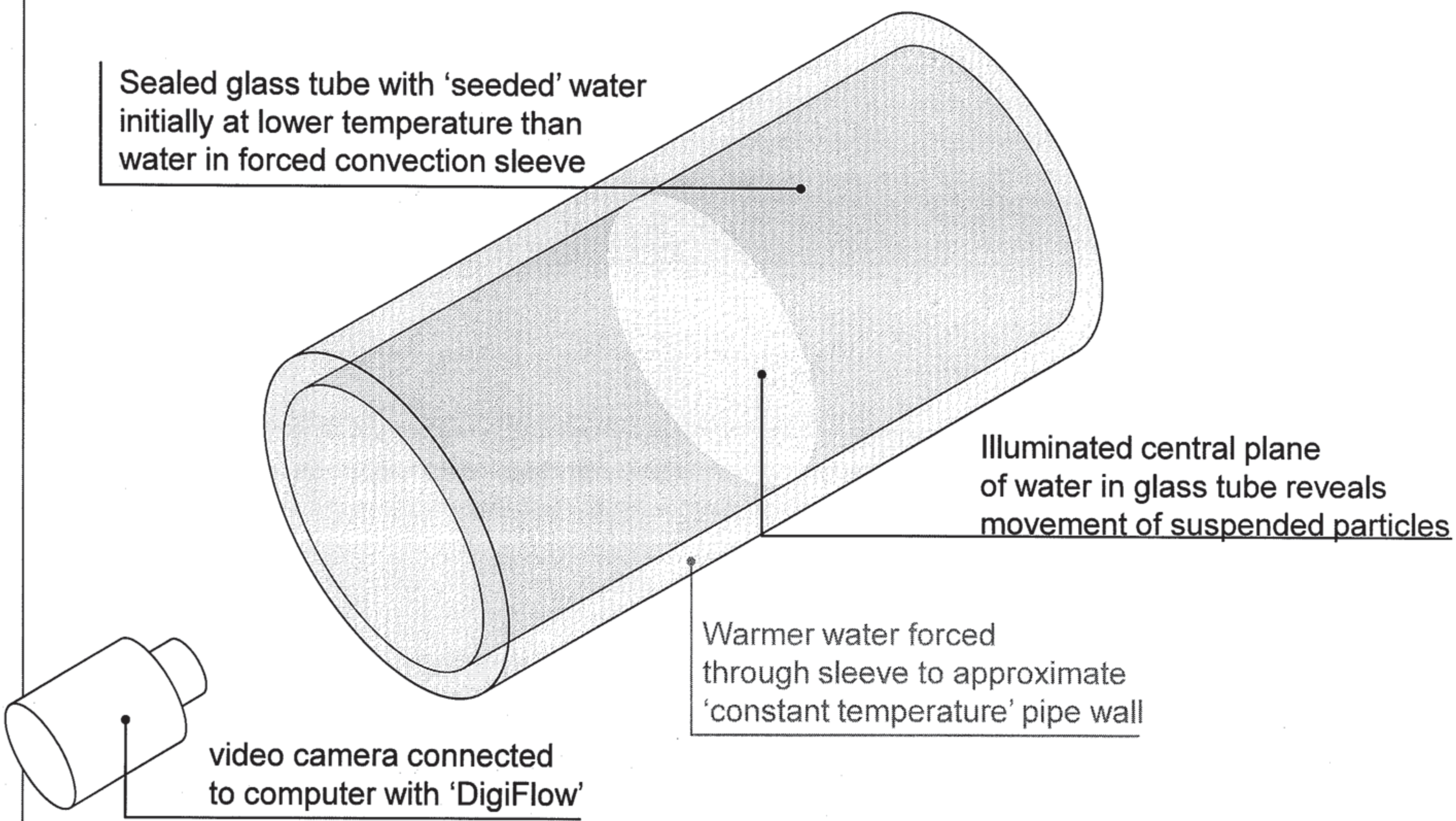
- Exposed high end



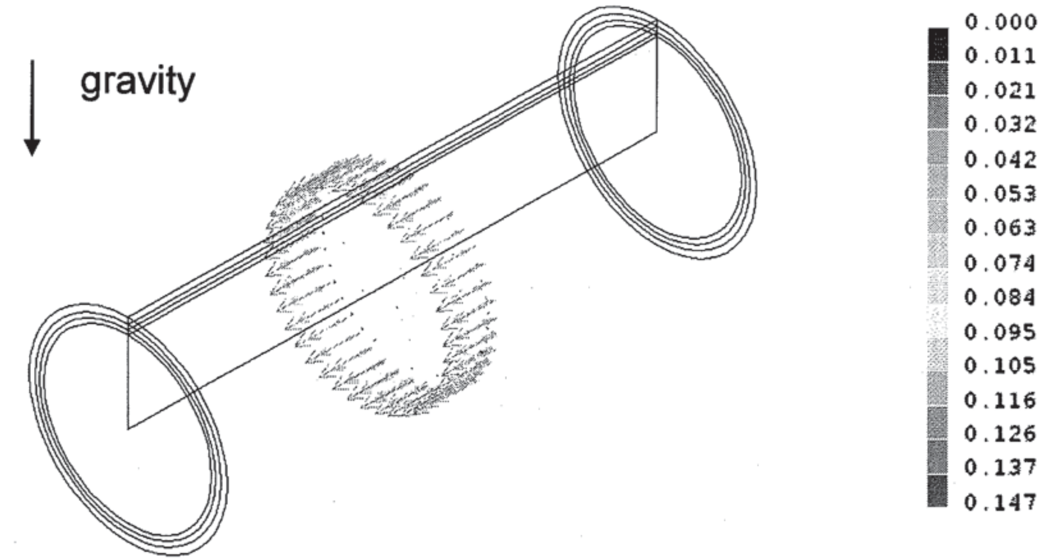
Variations in ‘mean’ temperatures over time

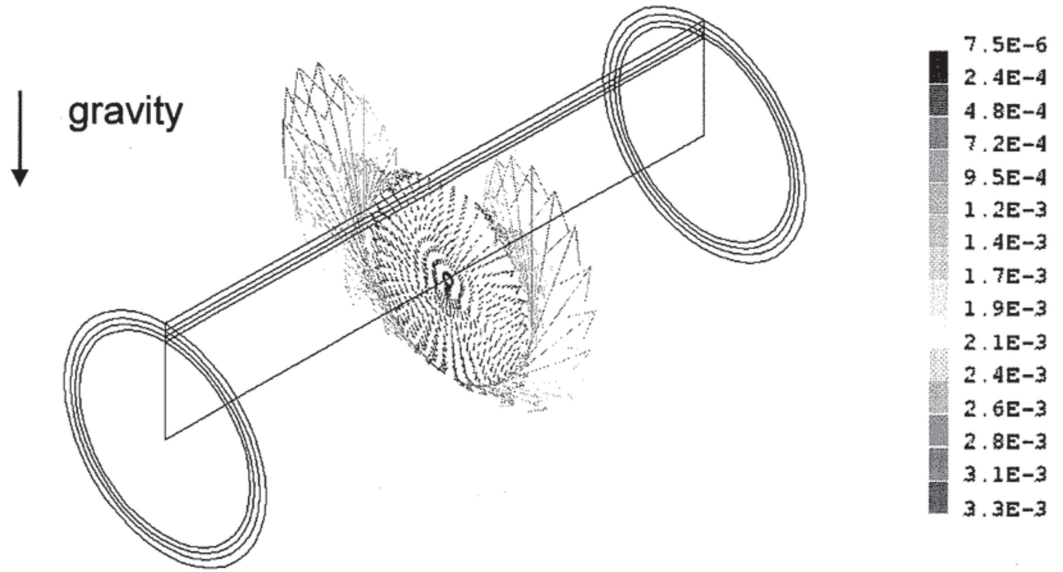
Proposed Experiment at UoW – schematic diagram

Purpose: To enable visualization of evolving buoyancy-driven flow inside pipeline initially warmer than filling water

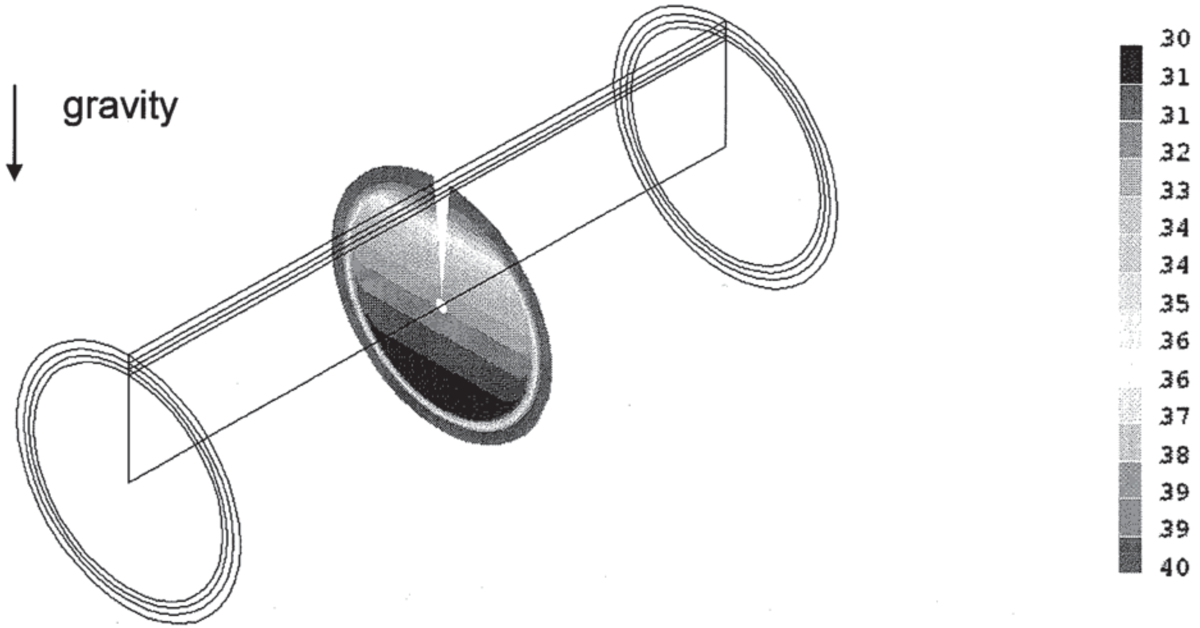


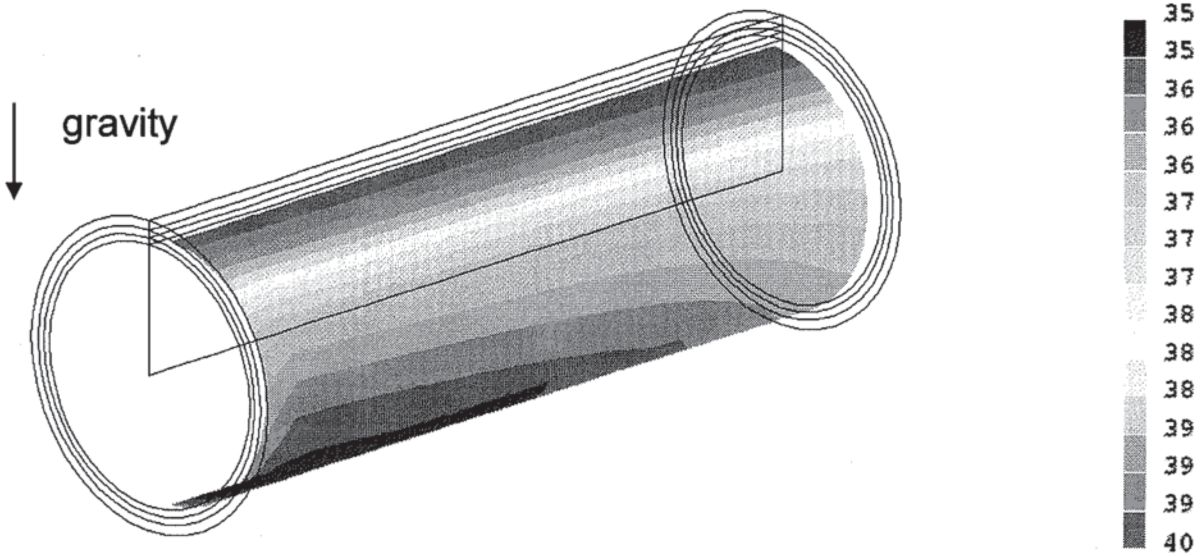
Proposed Experiment at UoW – CFD simulation





Proposed Experiment at UoW – CFD simulation





Proposed Experiment at UoW – CFD simulation

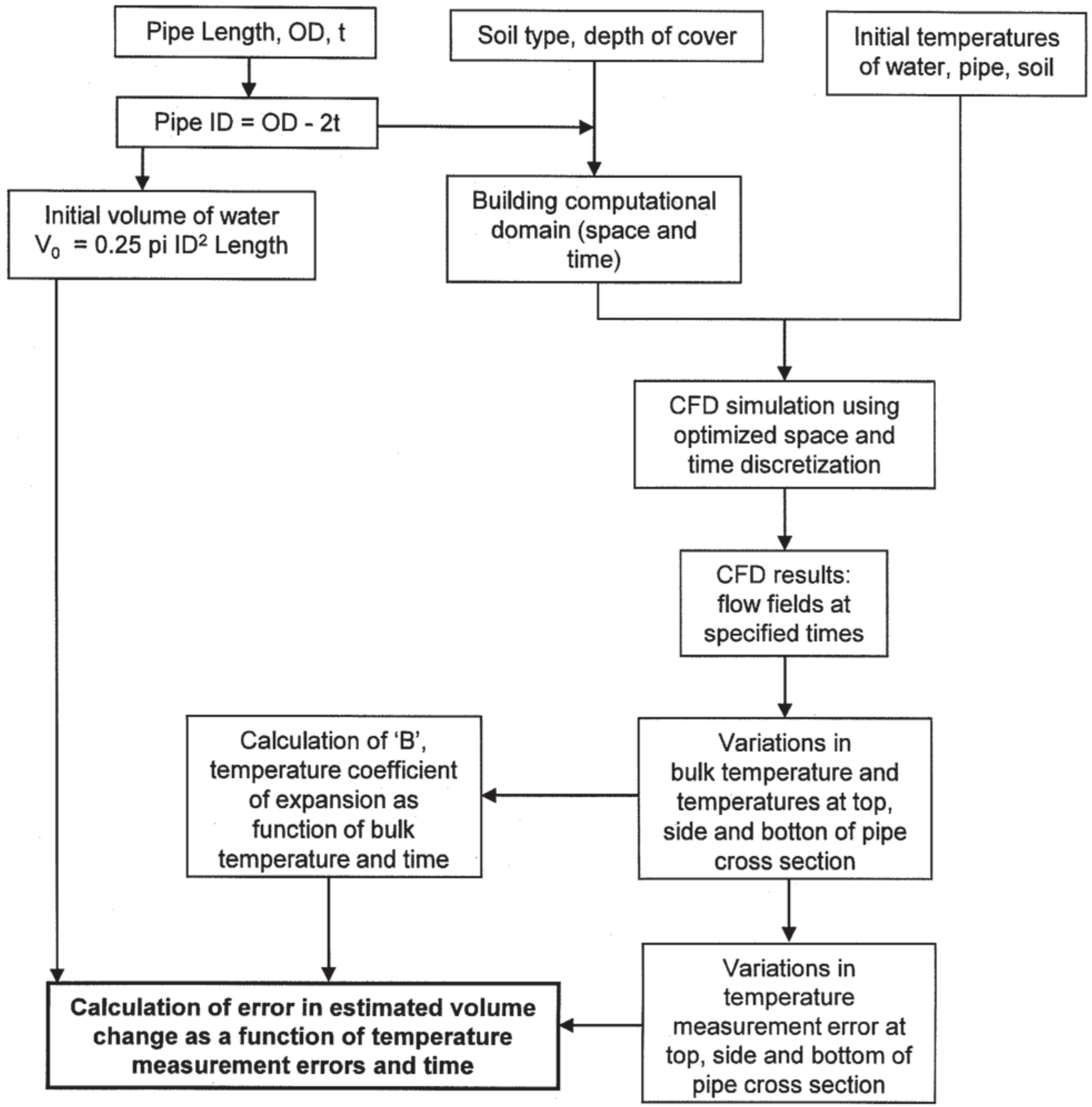
Estimation of Change in Test Fluid Volume

$$\Delta V = V_0 \left[\frac{1-\mu^2}{E} \cdot \frac{OD}{t} + A \right] \Delta p - V_0 B \Delta T$$

where:

- ΔV = Change in test fluid volume
- V_0 = Original Volume
- μ = Poisson's Ratio for pipe wall material
- E = Modulus of elasticity of pipe wall material
- A = Compressibility of test fluid
- t = Pipe wall thickness
- Δp = Change in pressure
- B = Temperature coefficient of expansion of test fluid
- ΔT = Change in test fluid temperature

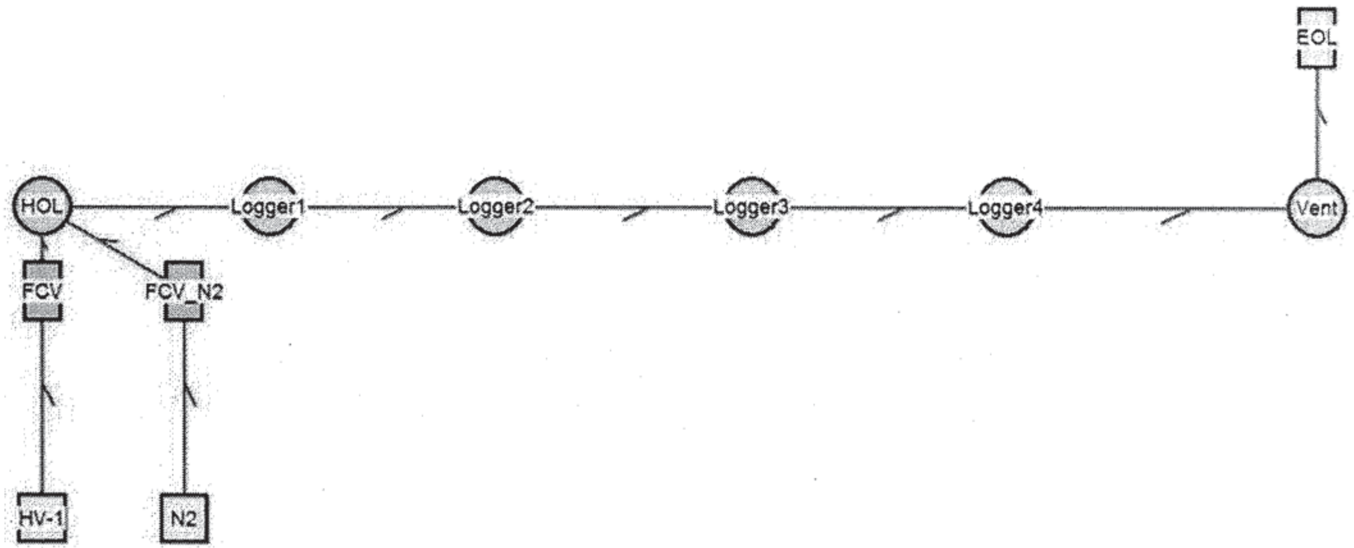
Estimation of Error in Volume Change

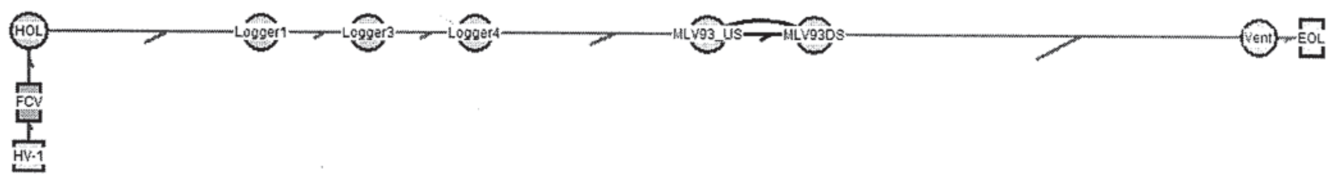


CFD Analyses

Pipe Dimensions	Soil	Depth of cover	Duration
DN 250 OD 273.1 mm wall thickness 4 mm	Wet Sandstone	1 m	24 hours and 48 hours
	Silty Clay 10% moisture	1 m	24 hours
	Dry Topsoil	1 m	24 hours
DN 500 OD 508 mm wall thickness 7.5 mm	Wet Sandstone	1 m	24 hours
	Silty Clay 10% moisture	1 m	24 hours
	Dry Topsoil	1 m	24 hours
DN 1000 OD 1016 mm wall thickness 14.9 mm	Wet Sandstone	1 m	24 hours
	Silty Clay 10% moisture	1 m	24 hours
	Dry Topsoil	1 m	24 hours

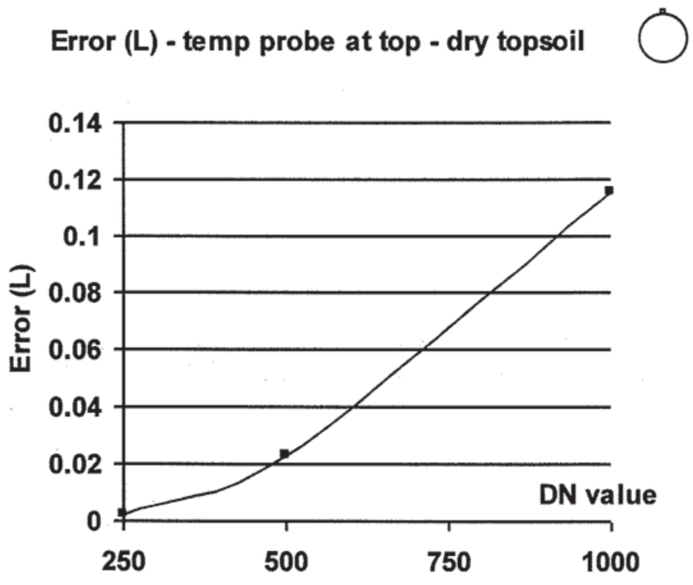
	Thermal Conductivity (W/mK)	Density (kg/m^3)	Specific Heat (J/kgK)	Thermal Diffusivity (m^2/s)
Wet Sandstone	2.08	1784	1979.49	5.89e-7
Silty Clay (10%moisture)	1.18	1700	1928.10	3.60e-7
Dry Topsoil	0.52	1840	3754.60	1.38e-7
FBE Coating	0.50	965	1000.0 (assumed)	5.18e-7


HOL
FCV
FCV_N2
HV-1
N2
Logger1
Logger2
Logger3
Logger4
Vent
EOL

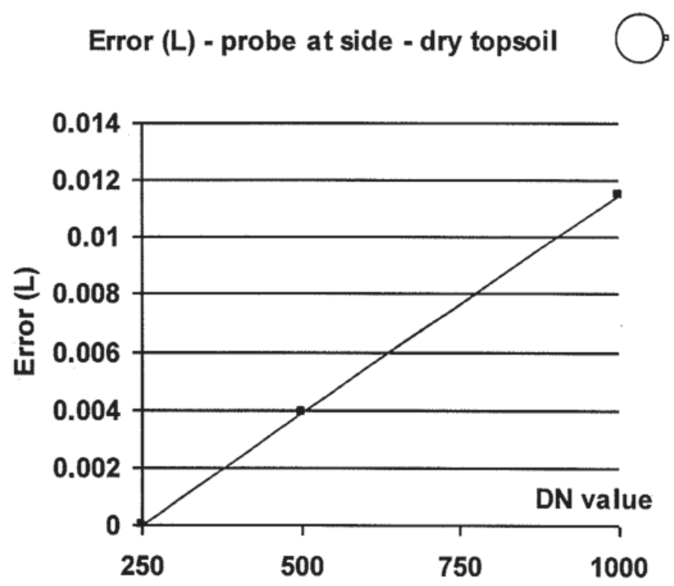

HOL
FCV
HV-1
Logger1
Logger3
Logger4
MLV93_US
MLV93DS
Vent
EOL

Estimation of Error for different pipe sizes and soil types

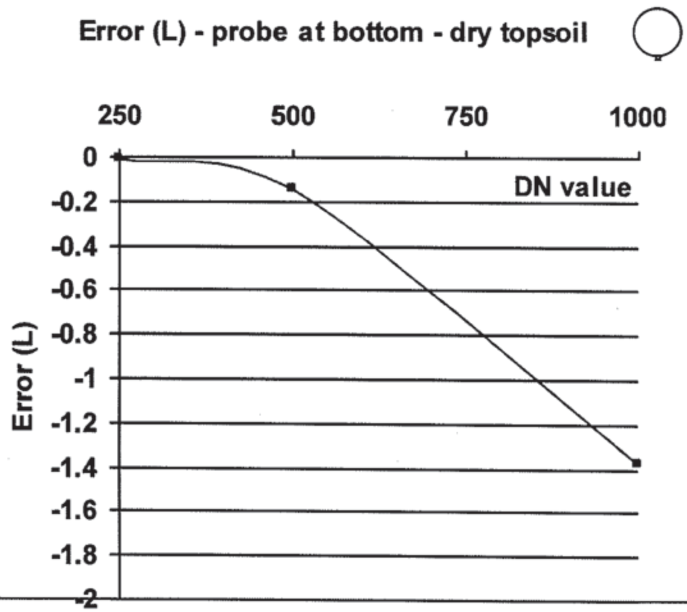
Error (L) - temp probe at top - dry topsoil



Error (L) - probe at side - dry topsoil



Error (L) - probe at bottom - dry topsoil



Thank you !